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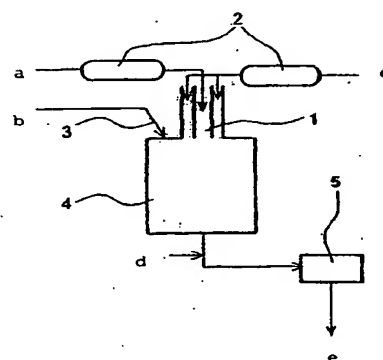
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**(54) PROCESS FOR PRODUCING FINELY PARTICULATE OXIDE COMPOSITE CONTAINING  
TITANIUM OXIDE**

(57) A process for the vapor-phase production of an oxide composite containing titanium oxide, characterized by preheating a feed gas comprising titanium tetrachloride and an oxidizing gas to 700°C or higher and reacting them with a solution or slurry of a salt containing a metal element to produce a finely particulate oxide composite having a BET specific surface area of 5 to 200 m<sup>2</sup>/g; a titanium oxide-containing oxide composite obtained by the process; and a composition containing the composite. Thus, a finely particulate oxide composite which contains titanium oxide and has a practical value can be produced by the industrially advantageous and simple process.

Fig. 1



a...TITANIUM TETRACHLORIDE (AND DILUTING GAS)  
b...AQUEOUS SALT SOLUTION CONTAINING METAL ELEMENT  
c...OXYGEN AND WATER VAPOR  
d...COOLING AIR  
e...FINELY PARTICULATE COMPOSITE OXIDE CONTAINING  
TITANIUM OXIDE

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## Description

## Technical Field

5 [0001] The present invention relates to a production process for a complex oxide containing titanium oxide obtained by a vapor phase method. More specifically, the present invention relates to a complex oxide containing titanium oxide starting from titanium tetrachloride and a solution or slurry of a salt containing a metallic element, and also relates to a process for producing the complex oxide and a composition containing the complex oxide.

## 10 Background Art

[0002] The industrial field where ultrafine particulate titanium oxide is applied is recently expanding. For example, studies are being made on uses over a wide range such as starting material for high-performance dielectric, ultraviolet-shielding material, additive to silicone rubber and photocatalytic material.

15 [0003] Use as a starting material for Perovskite-type dielectric is described below.

[0004] As shown in the following reaction formula, titanium oxide is subjected to a solid phase reaction with barium carbonate at a temperature of about 1,200°C to produce a barium titanate dielectric material:



[0005] In this case, barium carbonate decomposes at about 700°C to produce BaO having high ionicity and this BaO causes diffusion and solid solution into a TiO<sub>2</sub> particle having a covalent bonding property to produce barium titanate. The particle size of barium titanate is decided by the crystal size of TiO<sub>2</sub> at the time of reaction and therefore, the crystallinity, the particle size and the like of titanium oxide as a starting material are important.

25 [0006] Also, to cope with the requirement for higher dielectric constant or smaller size of a ceramic capacitor, ultrafine particulate barium titanate is demanded and heretofore, investigations have been made for forming ultrafine particles of titanium oxide as a starting material. The ultrafine particle is not clearly defined so far but, in general, indicates a fine particle having a primary particle size of about 0.1 μm or less.

30 [0007] However, titanium oxide particles having a particle size of 0.1 μm or less undertake vigorous growth in the vicinity of the above-described reaction temperature of 700°C and disadvantageously fail in contributing to the formation of ultrafine particulate barium titanate. Accordingly, titanium oxide suitable solving such a problem is being demanded.

[0008] By taking notice of the photocatalytic activity, uses for the antifouling, sterilization or deodorization purpose, or by taking notice of the ultraviolet-shielding effect, uses for cosmetic materials are attracting an attention. These uses are supported by excellent safety, processability, functionality and durability of titanium oxide.

35 [0009] Photocatalysis is described below.

[0010] Titanium oxide has a property of absorbing an ultraviolet ray at a wavelength of about 400 nm or less and exciting an electron. An electron and a hole generated and reached the particle surface combine with oxygen or water to generate various radicals. These radicals mainly show an oxidation activity and decompose by oxidation substances adhering to the surface. This is a basic principle of photocatalysis.

40 [0011] In order to enhance the photocatalytic activity, for example, the following methods are used.

(1) To reduce particle size

45 [0012] This is very effective for inhibiting recombination of an electron and a hole generated.

(2) To enhance crystallinity

[0013] This is effective for increasing the diffusion rate of an electron and a hole generated to the surface.

50 (3) To perform charge separation

[0014] An electron and a hole generated are subjected to charge separation and the yield thereof reaching the surface is increased.

55 (4) To control band gap

[0015] The band gap is reduced (maximum absorption wavelength is increased) by adding trace impurities, whereby

use ratio of light, for example, sunlight can be elevated.

[0016] Among these means, various additives are being studied for the purpose of (3) and (4) in recent years.

[0017] In order to coat fine particulate titanium oxide having the above-described photocatalytic effect on a support, a method of coating a slurry obtained by mixing it with a binder on a support and then baking the coating at 600°C or more may be used. However, at this time, primary particles grow due to sintering, as a result, the catalytic activity disadvantageously decreases.

[0018] Conventionally, in the production process of fine particulate composite oxide containing titanium oxide, a surface treatment by a liquid phase method is a representative process. However, this process has a problem in that a step of removing a solvent, namely, filtration and drying is necessary and moreover, in the case where the solvent is water, the water works out to a binder and accelerates the coagulation and therefore, a step of strongly cracking or pulverizing the agglomerate is required. Furthermore, when an organic solvent is employed, a system for recovering the solvent is necessary and a cumbersome production process results.

[0019] JP-A-11-228139 (the term "JP-A" as used herein means an "unexamined published Japanese patent application") discloses a technique of obtaining a composite powder material by atomizing and combusting an emulsion starting from an organic solvent/dispersant and an aqueous solution having dissolved therein a salt containing titanium oxide of BET 15 m<sup>2</sup>/g or more and a metallic element. This method is, however, disadvantageous in that the process takes a long time and a large amount of a flammable solvent is necessary for the combustion.

#### Object of the Invention

[0020] By taking account of the above-described uses of fine particulate metal oxide, the object of the present invention is to provide a simple and easy process for producing ultrafine particulate complex oxide (sometimes also called "compound oxide") containing titanium oxide. The object of the present invention includes providing the complex oxide and a composition containing the complex oxide.

#### Summary of the Invention

[0021] As a result of extensive investigations on conventional techniques, the present inventors have found that the above-described problems can be solved by producing an ultrafine particulate complex oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g by a one-stage reaction, more specifically, in the vapor phase process for producing a complex oxide containing titanium oxide, by reacting a starting material gas containing titanium tetrachloride, an oxidizing gas, each gas being pre-heated at 700°C or more, and a solution or slurry of a salt containing a metallic element.

[0022] That is, the present invention relates to a process for producing a complex oxide containing titanium oxide, the complex oxide containing titanium oxide obtained by the process and a composition containing the complex oxide.

(1) A process for producing ultrafine particulate complex oxide containing titanium oxide, comprising vapor-phase producing a complex oxide containing titanium oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g, wherein a starting material gas containing titanium tetrachloride and an oxidizing gas, each gas being preheated to 700°C or more, are reacted with a solution or a slurry of a salt containing a metallic element.

(2) The process for producing a complex oxide containing titanium oxide as described in 1 above, wherein the complex oxide contains a titanium-oxygen-metallic element bond.

(3) The process for producing a complex oxide containing titanium oxide as described in 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing a transition metal element.

(4) The process for producing a complex oxide containing titanium oxide as described in 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing an alkaline earth metal.

(5) The process for producing a complex oxide containing titanium oxide as described in 1 or 2, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing an alkali metal.

(6) The process for producing a complex oxide containing titanium oxide as described in 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing a metal of Group IIb or IVb.

(7) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 6 above, wherein the solvent of the solution or slurry having a boiling point of 40°C or more at an atmospheric pressure is used.

(8) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 7 above, wherein the solution or slurry is fed at a position upstream from the point of initiating the reaction of the starting

material gas containing titanium tetrachloride with the oxidizing gas.

(9) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 7 above, wherein the solution or slurry is fed between the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas and the position 200 mm downstream from the point.

(10) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 9, wherein the solution or slurry is fed in the atomized state.

(11) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 10 above, wherein the reaction is performed by feeding the starting material gas containing titanium tetrachloride and the oxidizing gas, each gas being preheated at 700°C or more, to a reaction tube each at a velocity of 10 m/sec or more.

(12) The process for producing a complex oxide containing titanium oxide as described in 11 above, wherein the reaction is performed by allowing the starting material gas containing titanium tetrachloride and the oxidizing gas to stay in the reaction tube under a temperature condition such that the temperature within the reaction tube exceeds 600°C, for a time period of 1.0 second or less.

(13) The process for producing a complex oxide containing titanium oxide as described in 11 or 12 above, wherein the average velocity of the starting material gas within the reaction tube is 5 m/sec or more.

(14) The process for producing a complex oxide containing titanium oxide as described in any one of 11 to 13 above, wherein a turbulence is generated upon feeding of the starting material gas containing titanium tetrachloride and the oxidizing gas, each gas being preheated, into the reaction tube.

(15) The process for producing a complex oxide containing titanium oxide as described in any one of 11 to 14 above, wherein the starting material gas containing titanium tetrachloride and the oxidizing gas are fed into the reaction tube through a coaxial parallel-flow nozzle and the inner tube of the coaxial parallel-flow nozzle has an inside diameter of 50 mm or less.

(16) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 15, wherein as the starting material gas containing titanium tetrachloride, gaseous titanium tetrachloride and a gas containing 10 vol% or more of titanium tetrachloride diluted by an inert gas are used.

(17) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 16 above, wherein the starting material gas containing titanium tetrachloride and the oxidizing gas each is preheated at 1,000°C or more.

(18) An ultrafine particulate complex oxide containing titanium oxide, which is produced by the production process as described in any one of 1 to 17 above.

(19) An ultrafine particulate complex oxide containing titanium oxide, which is an ultrafine particulate complex oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g.

(20) An ultrafine particulate complex oxide containing titanium oxide as described in 19, which is in the mixed crystal state of allowing a titanium-oxygen-metallic element bond to be present within a primary particle.

(21) An ultrafine particulate complex oxide containing titanium oxide as described in any one of 18 to 20 above, wherein the average primary particle size is from 0.008 to 0.3 μm.

(22) An ultrafine particulate complex oxide containing titanium oxide as described in any one of 18 to 21, wherein the decrease ratio of the BET specific surface area after heating at 700°C for 1 hour is 20% or less.

(23) A composition comprising one ultrafine particulate complex oxide, which contains ultrafine particulate complex oxide containing titanium oxide as described in any one of 18 to 22 above.

#### Brief Description of Drawing

[0023] Fig. 1 is a schematic view roughly showing an example of the reaction tube with a coaxial parallel-flow nozzle suitably used in the present invention.

#### Disclosure of the Invention

[0024] The present invention is described in detail below.

[0025] The present invention relates to a production process of a complex oxide containing titanium oxide, characterized in that in a vapor phase method of oxidizing mainly titanium tetrachloride with an oxidizing gas at a high temperature to produce an ultrafine particulate complex oxide containing titanium oxide, a starting material gas containing titanium tetrachloride, an oxidizing gas, each gas being preheated at 700°C or more, and a solution or slurry of a salt containing a metallic element are reacted and thereby, an ultrafine particulate complex oxide containing titanium oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g can be produced by a one-stage reaction.

[0026] In the process for producing an ultrafine particulate complex oxide containing titanium oxide of the present invention, the oxidizing gas is oxygen, water vapor or a mixed gas thereof.

[0027] In the present invention, the starting material gas containing titanium tetrachloride and the oxidizing gas each

must be preheated at a temperature of at least 700°C or more, preferably 900°C or more, before the reaction. If the preheating temperature of the starting material gas containing titanium tetrachloride and the oxidizing gas is less than 700°C, the reactivity deteriorates in the reaction with a solution or slurry of a salt containing a metallic element, as a result, ultrafine particles are difficult to form and at the same time, the residual chlorine after dechlorinating increases.

**[0028]** In the present invention, the starting material gas containing titanium tetrachloride and the oxidizing gas each is suitably fed into a reaction tube at a velocity of 10 m/sec or more, preferably 30 m/sec or more. These gases are preferably reacted to allow the gases to stay and react within the reaction tube under a high-temperature condition in excess of 600°C for 1.0 second or less (hereinafter sometimes referred to as a "high-temperature residence time").

**[0029]** In particular, as a result of extensive investigations on the growing mechanism of particles in a gas phase method, the present inventors have found that ultrafine particulate oxide can be obtained preferably by controlling, as factors acting on the growth of particles, CVD (chemical vapor deposition) mechanism and the combining/sintering growth mechanism due to the collision of particles (by reducing the growing time in either growth). More specifically, in the former growth, the preheating temperature is elevated to enhance the chemical reactivity (reaction rate) and thereby, the growth of oxide can be suppressed. In the latter growth, after the completion of CVD, the system is swiftly subjected to cooling, dilution or the like to reduce the high-temperature residence time as much as possible, whereby the growth due to sintering or the like can be suppressed. By selecting the production conditions as such, an ultrafine particulate complex oxide containing titanium oxide, having a BET specific surface area of 5 to 200 m<sup>2</sup>/g, preferably from 10 to 100 m<sup>2</sup>/g, can be obtained.

**[0030]** The velocity at the time of introducing the starting material gas containing titanium tetrachloride and the oxidizing gas into a reaction tube is preferably 10 m/sec or more, because by increasing the velocity, the mixing of two gases is accelerated. When the temperature at the introduction of gases into a reaction tube is 700°C or more, the reaction is completed simultaneously with the mixing and therefore, the generation of uniform nuclei is encouraged and at the same time, the zone of causing formation of particles grown under CVD control can be shortened.

**[0031]** In the present invention, the starting material is preferably introduced into a reaction tube so that the gases introduced into the reaction tube can be thoroughly mixed. As long as the gases are thoroughly mixed, the fluid state of gases within the reaction tube is not particularly limited but, for example, a fluid state of causing turbulence is preferred. A vortex flow may also be present.

**[0032]** There is a method, for example, of increasing the velocity in order to introduce sufficiently the starting material gas mixed in a fluid state of causing turbulence or in a state of causing a vortex flow. Usually, a vortex flow occurs when the velocity is more than 30 m/sec.

**[0033]** In the present invention, the starting material gas and an oxidizing gas fed into the reaction tube preferably flow at a higher rate so as to perform a complete mixing of the gases. Particularly, the average velocity is preferably 5 m/sec or more. When the gases flow at a velocity of 5 m/sec or more within the reaction tube, the gases can be satisfactorily mixed within the reaction tube.

**[0034]** The inlet nozzle for introducing the starting material gas into the reaction tube may be a nozzle of giving coaxial parallel flow, oblique flow, cross flow or the like but the present invention is not limited thereto. In general, the coaxial parallel-flow nozzle is inferior in the mixing degree to the nozzle of giving oblique flow or cross flow but is preferably used in view of the design because of its simple structure. For example, in the case of a coaxial parallel-flow nozzle, the starting material gas containing a titanium tetrachloride is introduced into the inner tube and the oxidizing gas is introduced into the outer tube. In view of the mixing of gases, the inner diameter is preferably 50 mm or less, more preferably from 10 to 50 mm.

**[0035]** Salts containing a metallic element are reacted with the above mentioned starting material gas and an oxidizing gas in the present invention.

**[0036]** A metallic element is elements shown in Table 1. The metallic element is preferably a transition metallic element, an alkaline earth metal, an alkali metal element or a metal of Group IIb or IVb.

Table 1

## Elements Defined as Metallic Element

	Ia	IIa	IIIA	IVA	Va	VIA	VIIa	VIII	Ib	IIB	IIIB	IVb	Vb	VIB	VIIb	O
1																
2	3 Li	4 Be									5 B					
3	11 Na	12 Mg									13 Al	14 Si	15 P			
4	19 K	20 Ca	21 Sc		23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te
6	55 Cs	56 Ba	(LAN)	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po
7	87 Fr	88 Ra	(ACT)													85 At

Lanthanide (rare earth)	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinoid	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

[0037] The salt containing a metallic element may be at least one freely selected from a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt of the above-mentioned metal elements.

[0038] The salt containing a metallic element may be fed into a reactor in the solution or slurry state but is preferably fed in the solution state.

[0039] The solvent of a solution or a slurry is preferably a solvent having a boiling point of 40°C or more at an atmospheric pressure. Specific examples thereof include water, methanol, ethanol, propanol, 2-propanol, 1-butanol, 2-butanol, acetone, methyl ethyl ketone, dibutyl ether, N,N-dimethylformamide, dimethyl sulfoxide, formic acid, acetic acid, ethyl acetate, benzene, toluene, hexane and octane. Among these, in view of polarity and handleability, water is preferred. If the boiling point is less than 40°C, the solvent may be evaporated within the feeding nozzle and this is not preferred.

[0040] The solution or slurry may be fed at a position upstream from the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas or may be fed between the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas and the position 200 mm downstream from the point, according to the flowing direction. If the feeding point is more downstream, the additive distribution in the produced oxide disadvantageously becomes non-uniform.

[0041] The solution or slurry may also be fed by the dropwise addition or atomization to the reaction mixture of the starting material gas containing titanium tetrachloride and the oxidizing gas. In view of uniform mixing, the solution or slurry is preferably fed in the atomized state.

[0042] The reaction within the reaction tube is an exothermic reaction. If the reaction temperature is higher than the sintering temperature of the produced ultrafine particulate complex oxide containing titanium oxide, unless the produced fine particles are rapidly cooled, sintering thereof proceeds to give grown particles. The reaction temperature is also preferably 600°C or more. If the reaction temperature is less than this range, the reactivity is bad, the addition yield of metal is low and fine particles are difficult to form. In the present invention, it is preferred that the preheating temperature of starting material gas and the amount of solution or slurry of the metal added are adjusted, the reaction temperature is set to 600°C or more, the high-temperature residence time in excess of 600°C within the reaction tube is set to 1.0 second or less, and the particles after the reaction are rapidly cooled.

[0043] For rapidly cooling the particles after the reaction, a method of introducing a large amount of cooling air or gas such as nitrogen into the mixture after the reaction or a method of spraying water thereon may be used.

[0044] Fig. 1 is a schematic view roughly showing an example of a reaction tube with a coaxial parallel-flow nozzle for use in the production of an ultrafine particulate composite oxide of the present invention. The starting material gas containing titanium tetrachloride is pre-heated to a predetermined temperature by a preheating unit 2 and introduced into the reaction tube 4 through the inner tube of a coaxial parallel-flow nozzle 1. The oxidizing gas is preheated to a predetermined temperature by the preheating unit 2 and introduced into the reaction tube 4 through the outer tube of the coaxial parallel-flow nozzle 1. The salt solution or slurry containing a metallic element is introduced into the reaction mixture of the titanium tetrachloride and the oxidizing gas from the outside of the nozzle through an inlet nozzle 3. The gases and the salt solution or slurry containing a metallic element introduced into the reaction tube are mixed, reacted, rapidly cooled by a cooling gas and thereafter, transferred to a bag filter 5 where the ultrafine particulate complex oxide is collected. A dechlorinating treatment was performed by heating the collected particles in an oven at 300 to 600 °C for a half an hour to 4 hours in an air atmosphere.

[0045] The starting material gas containing titanium tetrachloride may be used in the form of a 100 vol% titanium tetrachloride gas as it is but is preferably charged after diluting it with an inert gas to a concentration of 10 to less than 100 vol%, preferably from 20 to less than 100 vol%. By using a gas of 10 vol% or more as a starting material, generation of uniform nuclei increases and the reactivity is enhanced. The inert gas is selected from those which are not reactive with titanium tetrachloride and not oxidized. To speak specifically, the diluting gas is preferably nitrogen, argon or the like.

[0046] The ultrafine particulate complex oxide obtained by the production process of the present invention is described below. The average primary particle size of the ultrafine particulate complex oxide of the present invention is from 0.008 to 0.3 µm, preferably from 0.015 to 0.15 µm.

[0047] As an index (the evaluation method is described later) for sintering resistance of the ultrafine particulate complex oxide, the decrease ratio of BET specific surface area after the heating is evaluated, as a result, the decrease ratio of BET specific surface area of the fine particulate complex oxide containing a titanium-oxygen-metal bond is 20% or less after the heating at 700°C for 1 hour.

[0048] The ultrafine particulate complex oxide obtained by the production process of the present invention may take a core/shell structure preferably having a dissimilar metal oxide crystal structure. For example, in the case of a titanium-metal ultrafine particulate complex oxide containing a mixed crystal state where a titanium-oxygen-dissimilar metal bond is present within the primary particle, a structure such that a TiO<sub>2</sub> phase is rich in the core and a dissimilar metal oxide phase is rich in the shell is observed.

[0049] The ultrafine particulate complex oxide of the present invention can be singly used for a pigment or a dielectric

starting material or as a composition containing the complex oxide, used for various compositions and products such as cosmetic, cloth, ultraviolet-shielding agent, abrasive, silicon rubber or paper. The ultrafine particulate complex oxide of the present invention can also be used as a photocatalytic powder material controlled in the photocatalytic effect.

## Best Mode for Carrying Out The Invention

[0050] The present invention is described in greater detail below by referring to the Examples, however, the present invention is not limited to these examples.

### [Evaluation of Sintering Resistance]

[0051] The decrease ratio of BET specific surface area after heating is employed as an index for evaluating sintering resistance of the ultrafine particulate complex oxide of the present invention.

[0052] In an alumina-made crucible, 1 g of a starting powder material was charged and in a Siliconit oven, heated at 700°C for 1 hour. After cooling to room temperature, the BET specific surface area was measured. Assuming that the BET specific surface area of the starting powder material is B1 (m<sup>2</sup>/g) and the BET specific surface area after the heating is B2 (m<sup>2</sup>/g),

Decrease ratio of BET specific surface area =

$$\{1-(B2/B1)\} \times 100 (\%)$$

As the decrease ratio of BET specific surface area is smaller, the sintering resistance is judged higher.

### (Evaluation of Mixed Crystal State)

[0053] In the present invention, XPS (X-ray photoelectron spectroscopy) is employed for confirming the mixed crystal state. The details thereon are described in A. Yu. Stakheev et al., *J. Phys. Chem.*, 97(21), 5668-5672 (1993), and the like.

#### Example 1

[0054] A reaction tube shown in Fig. 1 whose inner tube of a coaxial parallel-flow nozzle had a diameter of 20 mm was used. 11.8 Nm<sup>3</sup>/hr (N means a standard state, hereinafter the same) of gaseous titanium tetrachloride in a concentration of 100 vol% and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 20 Nm<sup>3</sup>/hr of water vapor were preheated to 1,100°C and 1,000°C, respectively, and then titanium tetrachloride was introduced into the inner tube of a coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 53 m/sec and 50 m/sec, respectively. At this time, 3.7 kg/hr of an aqueous 20% zirconium oxychloride solution was sprayed from the outer circumferential part of the coaxial parallel-flow nozzle.

[0055] The inside velocity at a reaction temperature of 900°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.8 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0056] The thus-obtained titanium oxide had a BET specific surface area of 22 m<sup>2</sup>/g and an average primary particle size of 0.08 μm, and 0.8% of zirconium was detected. By XPS, a titanium-oxygen-zirconium bond was recognized.

[0057] The decrease ratio of BET specific surface area (hereinafter referred to as ΔB) after 700°C for 1 hour heating was 12%.

#### Example 2

[0058] By using a reaction tube shown in Fig. 1 whose inner tube of the coaxial parallel-flow nozzle had a diameter of 20 mm, a starting material gas containing titanium tetrachloride obtained by mixing 10.6 Nm<sup>3</sup>/hr of gaseous titanium tetrachloride and 6.0 Nm<sup>3</sup>/hr of nitrogen and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 30 Nm<sup>3</sup>/hr of water vapor were preheated to 1,100°C and 1,100°C, respectively, and then the gas containing titanium tetrachloride was introduced into the inner tube of the coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 74 m/sec and 66 m/sec, respectively. At this time, 7.1 kg/hr of an aqueous 20%



chromium trichloride solution was sprayed from the outer circumferential part of the coaxial parallel-flow nozzle.

[0059] The inside velocity at a reaction temperature of 1,000°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.9 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0060] The thus-obtained titanium oxide had a BET specific surface area of 34 m<sup>2</sup>/g and an average primary particle size of 0.04 μm, and 1.1% of chromium was detected. By XPS, a titanium-oxygen-chromium bond was recognized. The ΔB was 10%.

#### Example 3

[0061] By using a reaction tube shown in Fig. 1 whose inner tube of the coaxial parallel-flow nozzle had a diameter of 24 mm, a starting material gas containing titanium tetrachloride obtained by mixing 10.6 Nm<sup>3</sup>/hr of gaseous titanium tetrachloride and 10.0 Nm<sup>3</sup>/hr of nitrogen and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 30 Nm<sup>3</sup>/hr of water vapor were preheated to 1,050°C and 1,100°C, respectively, and then the gas containing titanium tetrachloride was introduced into the inner tube of the coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 64 m/sec and 36 m/sec, respectively. At this time, 6.5 kg/hr of an aqueous 20% magnesium nitrate solution was sprayed from the outer circumferential part of the coaxial parallel-flow nozzle.

[0062] The inside velocity at a reaction temperature of 1,000°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.9 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0063] The thus-obtained titanium oxide had a BET specific surface area of 40 m<sup>2</sup>/g and an average primary particle size of 0.04 μm, and 0.5% of magnesium was detected. By XPS, a titanium-oxygen-magnesium bond was recognized. The ΔB was 13%.

#### Comparative Example 1

[0064] By using a reaction tube shown in Fig. 1 whose inner tube of the coaxial parallel-flow nozzle had a diameter of 20 mm, 11.8 Nm<sup>3</sup>/hr of gaseous titanium tetrachloride in a concentration of 100 vol% and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 20 Nm<sup>3</sup>/hr of water vapor were preheated to 1,000°C and 900°C, respectively, and then gaseous titanium tetrachloride was introduced into the inner tube of the coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 49 m/sec and 50 m/sec, respectively.

[0065] The inside velocity at a reaction temperature of 1,000°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.8 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0066] The thus-obtained titanium oxide had a BET specific surface area of 20 m<sup>2</sup>/g and an average primary particle size of 0.08 μm. The ΔB was 35% and this reveals that the sintering readily occurs as compared with the titanium oxide having similar specific surface area and particle size of Example 1.

#### Comparative Example 2

[0067] By using a reaction tube shown in Fig. 1 whose inner tube of the coaxial parallel-flow nozzle had a diameter of 20 mm, a starting material gas containing titanium tetrachloride obtained by mixing 10.6 Nm<sup>3</sup>/hr of gaseous titanium tetrachloride and 6.0 Nm<sup>3</sup>/hr of nitrogen and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 30 Nm<sup>3</sup>/hr of water vapor were preheated to 1,000°C and 800°C, respectively, and then the gas containing titanium tetrachloride was introduced into the inner tube of the coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 68 m/sec and 51 m/sec, respectively.

[0068] The inside velocity at a reaction temperature of 1,000°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.9 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0069] The thus-obtained titanium oxide had a BET specific surface area of 36 m<sup>2</sup>/g and an average primary particle size of 0.04 µm. The ΔB was 39% and this reveals that sintering readily occurs as compared with the titanium oxide having similar specific surface area and particle size of Example 2.

## 5 Industrial Applicability

[0070] According to the present invention, the starting material gas containing titanium tetrachloride and the oxidizing gas are each pre-heated to 700°C or more and reacted with a solution or slurry of a salt containing a metallic element, whereby an ultrafine particulate complex oxide containing titanium oxide having excellent sintering resistance and a  
10 BET specific surface area of 5 to 200 m<sup>2</sup>/g and containing primary particles in a mixed crystal state can be obtained by a one-stage reaction.

[0071] According to the production process of the present invention, the cracking step and the like can be dispensed with or even if required, the load of equipment is very small, thus, practically valuable ultrafine particulate complex oxide containing titanium oxide can be produced very easy and simple and industrially advantageously. Furthermore,  
15 according to the method of the present invention, the ultrafine particulate complex oxide whose sintering property or photoactivity are suppressed or controlled can be obtained.

## Claims

- 20 1. A process for producing ultrafine particulate complex oxide containing titanium oxide, comprising vapor-phase producing a complex oxide containing titanium oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g, wherein a starting material gas containing titanium tetrachloride and an oxidizing gas, each gas being preheated to 700°C or more, are reacted with a solution or a slurry of a salt containing a metallic element.
- 25 2. The process for producing a complex oxide containing titanium oxide as described in claim 1 above, wherein the complex oxide contains a titanium-oxide-metallic element bond.
- 30 3. The process for producing a complex oxide containing titanium oxide as described in claim 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing a transition metallic element.
- 35 4. The process for producing a complex oxide containing titanium oxide as described in claim 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing an alkaline earth metal.
- 40 5. The process for producing a complex oxide containing titanium oxide as described in claim 1 or 2, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing an alkali metal.
- 45 6. The process for producing a complex oxide containing titanium oxide as described in claim 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing a metal of Group IIb or IVb.
- 50 7. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 6 above, wherein the solvent of the solution or slurry having a boiling point of 40°C or more at an atmospheric pressure is used.
8. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 7 above, wherein the solution or slurry is fed at a position upstream from the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas.
- 55 9. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 7 above, wherein the solution or slurry is fed between the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas and the position 200 mm downstream from the point.
10. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 9, wherein the solution or slurry is fed in the atomized state.

11. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 10 above, wherein the reaction is performed by feeding the starting material gas containing titanium tetrachloride and the oxidizing gas, each gas being preheated at 700°C or more, to a reaction tube each at a velocity of 10 m/sec or more.
12. The process for producing a complex oxide containing titanium oxide as described in claim 11 above, wherein the reaction is performed by allowing the starting material gas containing titanium tetrachloride and the oxidizing gas to stay in the reaction tube under a temperature condition such that the temperature within the reaction tube exceeds 600°C, for a time period of 1.0 second or less.
13. The process for producing a complex oxide containing titanium oxide as described in claim 11 or 12 above, wherein the average velocity of the starting material gas within the reaction tube is 5 m/sec or more.
14. The process for producing a complex oxide containing titanium oxide as described in any one of claim 11 to 13 above, wherein a turbulence is generated upon feeding of the starting material gas containing titanium tetrachloride and the oxidizing gas, each gas being preheated, into the reaction tube.
15. The process for producing a complex oxide containing titanium oxide as described in any one of claims 11 to 14 above, wherein the starting material gas containing titanium tetrachloride and the oxidizing gas are fed into the reaction tube through a coaxial parallel-flow nozzle and the inner tube of the coaxial parallel-flow nozzle has an inside diameter of 50 mm or less.
16. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 15, wherein as the starting material gas containing titanium tetrachloride, gaseous titanium tetrachloride and a gas containing 10 vol% or more of titanium tetrachloride diluted by an inert gas are used.
17. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 16 above, wherein the starting material gas containing titanium tetrachloride and the oxidizing gas each is preheated at 1,000°C or more.
18. An ultrafine particulate complex oxide containing titanium oxide, which is produced by the production process as described in any one of claims 1 to 17 above.
19. An ultrafine particulate complex oxide containing titanium oxide, which is an ultrafine particulate complex oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g.
20. An ultrafine particulate complex oxide containing titanium oxide as described in claim 19, which is in the mixed crystal state of allowing a titanium-oxide-metallic element bond to be present within a primary particle.
21. An ultrafine particulate complex oxide containing titanium oxide as described in any one of claims 18 to 20 above, wherein the average primary particle size is from 0.008 to 0.3 μm.
22. An ultrafine particulate complex oxide containing titanium oxide as described in any one of claims 18 to 21, wherein the decrease ratio of the BET specific surface area after heating at 700°C for 1 hour is 20% or less.
23. A composition comprising one ultrafine particulate complex oxide, which contains ultrafine particulate complex oxide containing titanium oxide as described in any one of claims 18 to 22 above.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP01/03449

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. <sup>7</sup> C01G23/07		
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B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl. <sup>7</sup> C01G23/07		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2001 Kokai Jitsuyo Shinan Koho 1971-2001 Jitsuyo Shinan Toroku Koho 1996-2001		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3208866 A (E.I. du Pont de Nemours and Company), 28 December, 1965 (28.12.65), Claims; examples I-III; tables I, II (Family: none)	1-23
A	JP 8-502945 A (E.I. du Pont de Nemours and Company), 02 April, 1996 (02.04.96), Claims; working example & US 5201949 A & WO 9410089 A & EP 667836 A	1-23
A	JP 10-251021 A (Showa Denko K.K.), 22 September, 1998 (22.09.98), Claims; Par. Nos. [0018], [0019]; working example; table 1 (Family: none)	1-23
X	JP 9-315818 A (KOSE Corporation), 09 December, 1997 (09.12.97), Claims; working example (Family: none)	19-23
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
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## INTERNATIONAL SEARCH REPORT

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## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 11-197513 A (Sumitomo Osaka Cement Co., Ltd.), 27 July, 1999 (27.09.99), Claims; Par. No. {0027}; working example (Family: none)	19-23

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

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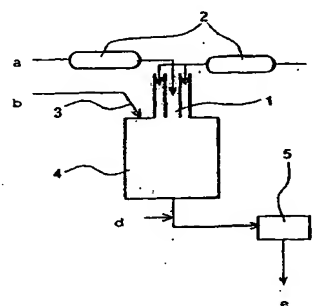
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(54) **PROCESS FOR PRODUCING FINELY PARTICULATE OXIDE COMPOSITE CONTAINING TITANIUM OXIDE**

(57) A process for the vapor-phase production of an oxide composite containing titanium oxide, characterized by preheating a feed gas comprising titanium tetrachloride and an oxidizing gas to 700°C or higher and reacting them with a solution or slurry of a salt containing a metal element to produce a finely particulate oxide composite having a BET specific surface area of 5 to 200 m<sup>2</sup>/g; a titanium oxide-containing oxide composite obtained by the process; and a composition containing the composite. Thus, a finely particulate oxide composite which contains titanium oxide and has a practical value can be produced by the industrially advantageous and simple process.

Fig. 1



a...TITANIUM TETRACHLORIDE (AND DILUTING GAS)  
b...AQUEOUS SALT SOLUTION CONTAINING METAL ELEMENT  
c...OXYGEN AND WATER VAPOR  
d...COOLING AIR  
e...FINELY PARTICULATE COMPOSITE OXIDE CONTAINING  
TITANIUM OXIDE

**EP 1 277 704 A9**

## Description

## Technical Field

5 [0001] The present invention relates to a production process for a complex oxide containing titanium oxide obtained by a vapor phase method. More specifically, the present invention relates to a complex oxide containing titanium oxide starting from titanium tetrachloride and a solution or slurry of a salt containing a metallic element, and also relates to a process for producing the complex oxide and a composition containing the complex oxide.

## 10 Background Art

[0002] The industrial field where ultrafine particulate titanium oxide is applied is recently expanding. For example, studies are being made on uses over a wide range such as starting material for high-performance dielectric, ultraviolet-shielding material, additive to silicone rubber and photocatalytic material.

15 [0003] Use as a starting material for Perovskite-type dielectric is described below.

[0004] As shown in the following reaction formula, titanium oxide is subjected to a solid phase reaction with barium carbonate at a temperature of about 1,200°C to produce a barium titanate dielectric material:



[0005] In this case, barium carbonate decomposes at about 700°C to produce BaO having high ionicity and this BaO causes diffusion and solid solution into a TiO<sub>2</sub> particle having a covalent bonding property to produce barium titanate. The particle size of barium titanate is decided by the crystal size of TiO<sub>2</sub> at the time of reaction and therefore, the crystallinity, the particle size and the like of titanium oxide as a starting material are important.

25 [0006] Also, to cope with the requirement for higher dielectric constant or smaller size of a ceramic capacitor, ultrafine particulate barium titanate is demanded and heretofore, investigations have been made for forming ultrafine particles of titanium oxide as a starting material. The ultrafine particle is not clearly defined so far but, in general, indicates a fine particle having a primary particle size of about 0.1 μm or less.

30 [0007] However, titanium oxide particles having a particle size of 0.1 μm or less undertake vigorous growth in the vicinity of the above-described reaction temperature of 700°C and disadvantageously fail in contributing to the formation of ultrafine particulate barium titanate. Accordingly, titanium oxide suitable solving such a problem is being demanded.

[0008] By taking notice of the photocatalytic activity, uses for the antifouling, sterilization or deodorization purpose, or by taking notice of the ultraviolet-shielding effect, uses for cosmetic materials are attracting an attention. These uses are supported by excellent safety, processability, functionality and durability of titanium oxide.

35 [0009] Photocatalysis is described below.

[0010] Titanium oxide has a property of absorbing an ultraviolet ray at a wavelength of about 400 nm or less and exciting an electron. An electron and a hole generated and reached the particle surface combine with oxygen or water to generate various radicals. These radicals mainly show an oxidation activity and decompose by oxidation substances adhering to the surface. This is a basic principle of photocatalysis.

40 [0011] In order to enhance the photocatalytic activity, for example, the following methods are used.

(1) To reduce particle size

45 [0012] This is very effective for inhibiting recombination of an electron and a hole generated.

(2) To enhance crystallinity

50 [0013] This is effective for increasing the diffusion rate of an electron and a hole generated to the surface.

(3) To perform charge separation

[0014] An electron and a hole generated are subjected to charge separation and the yield thereof reaching the surface is increased.

55 (4) To control band gap

[0015] The band gap is reduced (maximum absorption wavelength is increased) by adding trace impurities, whereby

use ratio of light, for example, sunlight can be elevated.

[0016] Among these means, various additives are being studied for the purpose of (3) and (4) in recent years.

[0017] In order to coat fine particulate titanium oxide having the above-described photocatalytic effect on a support, a method of coating a slurry obtained by mixing it with a binder on a support and then baking the coating at 600°C or more may be used. However, at this time, primary particles grow due to sintering, as a result, the catalytic activity disadvantageously decreases.

[0018] Conventionally, in the production process of fine particulate composite oxide containing titanium oxide, a surface treatment by a liquid phase method is a representative process. However, this process has a problem in that a step of removing a solvent, namely, filtration and drying is necessary and moreover, in the case where the solvent is water, the water works out to a binder and accelerates the coagulation and therefore, a step of strongly cracking or pulverizing the agglomerate is required. Furthermore, when an organic solvent is employed, a system for recovering the solvent is necessary and a cumbersome production process results.

[0019] JP-A-11-228139 (the term "JP-A" as used herein means an "unexamined published Japanese patent application") discloses a technique of obtaining a composite powder material by atomizing and combusting an emulsion starting from an organic solvent/dispersant and an aqueous solution having dissolved therein a salt containing titanium oxide of BET 15 m<sup>2</sup>/g or more and a metallic element. This method is, however, disadvantageous in that the process takes a long time and a large amount of a flammable solvent is necessary for the combustion.

#### Object of the Invention

[0020] By taking account of the above-described uses of fine particulate metal oxide, the object of the present invention is to provide a simple and easy process for producing ultrafine particulate complex oxide (sometimes also called "compound oxide") containing titanium oxide. The object of the present invention includes providing the complex oxide and a composition containing the complex oxide.

#### Summary of the Invention

[0021] As a result of extensive investigations on conventional techniques, the present inventors have found that the above-described problems can be solved by producing an ultrafine particulate complex oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g by a one-stage reaction, more specifically, in the vapor phase process for producing a complex oxide containing titanium oxide, by reacting a starting material gas containing titanium tetrachloride, an oxidizing gas, each gas being pre-heated at 700°C or more, and a solution or slurry of a salt containing a metallic element.

[0022] That is, the present invention relates to a process for producing a complex oxide containing titanium oxide, the complex oxide containing titanium oxide obtained by the process and a composition containing the complex oxide.

(1) A process for producing ultrafine particulate complex oxide containing titanium oxide, comprising vapor-phase producing a complex oxide containing titanium oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g, wherein a starting material gas containing titanium tetrachloride and an oxidizing gas, each gas being preheated to 700°C or more, are reacted with a solution or a slurry of a salt containing a metallic element.

(2) The process for producing a complex oxide containing titanium oxide as described in 1 above, wherein the complex oxide contains a titanium-oxygen-metallic element bond.

(3) The process for producing a complex oxide containing titanium oxide as described in 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing a transition metal element.

(4) The process for producing a complex oxide containing titanium oxide as described in 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing an alkaline earth metal.

(5) The process for producing a complex oxide containing titanium oxide as described in 1 or 2, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing an alkali metal.

(6) The process for producing a complex oxide containing titanium oxide as described in 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing a metal of Group IIb or IVb.

(7) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 6 above, wherein the solvent of the solution or slurry having a boiling point of 40°C or more at an atmospheric pressure is used.

(8) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 7 above, wherein the solution or slurry is fed at a position upstream from the point of initiating the reaction of the starting



material gas containing titanium tetrachloride with the oxidizing gas.

(9) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 7 above, wherein the solution or slurry is fed between the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas and the position 200 mm downstream from the point.

(10) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 9, wherein the solution or slurry is fed in the atomized state.

(11) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 10 above, wherein the reaction is performed by feeding the starting material gas containing titanium tetrachloride and the oxidizing gas, each gas being preheated at 700°C or more, to a reaction tube each at a velocity of 10 m/sec or more.

(12) The process for producing a complex oxide containing titanium oxide as described in 11 above, wherein the reaction is performed by allowing the starting material gas containing titanium tetrachloride and the oxidizing gas to stay in the reaction tube under a temperature condition such that the temperature within the reaction tube exceeds 600°C, for a time period of 1.0 second or less.

(13) The process for producing a complex oxide containing titanium oxide as described in 11 or 12 above, wherein the average velocity of the starting material gas within the reaction tube is 5 m/sec or more.

(14) The process for producing a complex oxide containing titanium oxide as described in any one of 11 to 13 above, wherein a turbulence is generated upon feeding of the starting material gas containing titanium tetrachloride and the oxidizing gas, each gas being preheated, into the reaction tube.

(15) The process for producing a complex oxide containing titanium oxide as described in any one of 11 to 14 above, wherein the starting material gas containing titanium tetrachloride and the oxidizing gas are fed into the reaction tube through a coaxial parallel-flow nozzle and the inner tube of the coaxial parallel-flow nozzle has an inside diameter of 50 mm or less.

(16) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 15, wherein as the starting material gas containing titanium tetrachloride, gaseous titanium tetrachloride and a gas containing 10 vol% or more of titanium tetrachloride diluted by an inert gas are used.

(17) The process for producing a complex oxide containing titanium oxide as described in any one of 1 to 16 above, wherein the starting material gas containing titanium tetrachloride and the oxidizing gas each is preheated at 1,000°C or more.

(18) An ultrafine particulate complex oxide containing titanium oxide, which is produced by the production process as described in any one of 1 to 17 above.

(19) An ultrafine particulate complex oxide containing titanium oxide, which is an ultrafine particulate complex oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g.

(20) An ultrafine particulate complex oxide containing titanium oxide as described in 19, which is in the mixed crystal state of allowing a titanium-oxygen-metallic element bond to be present within a primary particle.

(21) An ultrafine particulate complex oxide containing titanium oxide as described in any one of 18 to 20 above, wherein the average primary particle size is from 0.008 to 0.3 μm.

(22) An ultrafine particulate complex oxide containing titanium oxide as described in any one of 18 to 21, wherein the decrease ratio of the BET specific surface area after heating at 700°C for 1 hour is 20% or less.

(23) A composition comprising one ultrafine particulate complex oxide, which contains ultrafine particulate complex oxide containing titanium oxide as described in any one of 18 to 22 above.

#### Brief Description of Drawing

**[0023]** Fig. 1 is a schematic view roughly showing an example of the reaction tube with a coaxial parallel-flow nozzle suitably used in the present invention.

#### Disclosure of the Invention

**[0024]** The present invention is described in detail below.

**[0025]** The present invention relates to a production process of a complex oxide containing titanium oxide, characterized in that in a vapor phase method of oxidizing mainly titanium tetrachloride with an oxidizing gas at a high temperature to produce an ultrafine particulate complex oxide containing titanium oxide, a starting material gas containing titanium tetrachloride, an oxidizing gas, each gas being preheated at 700°C or more, and a solution or slurry of a salt containing a metallic element are reacted and thereby, an ultrafine particulate complex oxide containing titanium oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g can be produced by a one-stage reaction.

**[0026]** In the process for producing an ultrafine particulate complex oxide containing titanium oxide of the present invention, the oxidizing gas is oxygen, water vapor or a mixed gas thereof.

**[0027]** In the present invention, the starting material gas containing titanium tetrachloride and the oxidizing gas each

must be preheated at a temperature of at least 700°C or more, preferably 900°C or more, before the reaction. If the preheating temperature of the starting material gas containing titanium tetrachloride and the oxidizing gas is less than 700°C, the reactivity deteriorates in the reaction with a solution or slurry of a salt containing a metallic element, as a result, ultrafine particles are difficult to form and at the same time, the residual chlorine after dechlorinating increases.

**[0028]** In the present invention, the starting material gas containing titanium tetrachloride and the oxidizing gas each is suitably fed into a reaction tube at a velocity of 10 m/sec or more, preferably 30 m/sec or more. These gases are preferably reacted to allow the gases to stay and react within the reaction tube under a high-temperature condition in excess of 600°C for 1.0 second or less (hereinafter sometimes referred to as a "high-temperature residence time").

**[0029]** In particular, as a result of extensive investigations on the growing mechanism of particles in a gas phase method, the present inventors have found that ultrafine particulate oxide can be obtained preferably by controlling, as factors acting on the growth of particles, CVD (chemical vapor deposition) mechanism and the combining/sintering growth mechanism due to the collision of particles (by reducing the growing time in either growth). More specifically, in the former growth, the preheating temperature is elevated to enhance the chemical reactivity (reaction rate) and thereby, the growth of oxide can be suppressed. In the latter growth, after the completion of CVD, the system is swiftly subjected to cooling, dilution or the like to reduce the high-temperature residence time as much as possible, whereby the growth due to sintering or the like can be suppressed. By selecting the production conditions as such, an ultrafine particulate complex oxide containing titanium oxide, having a BET specific surface area of 5 to 200 m<sup>2</sup>/g, preferably from 10 to 100 m<sup>2</sup>/g, can be obtained.

**[0030]** The velocity at the time of introducing the starting material gas containing titanium tetrachloride and the oxidizing gas into a reaction tube is preferably 10 m/sec or more, because by increasing the velocity, the mixing of two gases is accelerated. When the temperature at the introduction of gases into a reaction tube is 700°C or more, the reaction is completed simultaneously with the mixing and therefore, the generation of uniform nuclei is encouraged and at the same time, the zone of causing formation of particles grown under CVD control can be shortened.

**[0031]** In the present invention, the starting material is preferably introduced into a reaction tube so that the gases introduced into the reaction tube can be thoroughly mixed. As long as the gases are thoroughly mixed, the fluid state of gases within the reaction tube is not particularly limited but, for example, a fluid state of causing turbulence is preferred. A vortex flow may also be present.

**[0032]** There is a method, for example, of increasing the velocity in order to introduce sufficiently the starting material gas mixed in a fluid state of causing turbulence or in a state of causing a vortex flow. Usually, a vortex flow occurs when the velocity is more than 30 m/sec.

**[0033]** In the present invention, the starting material gas and an oxidizing gas fed into the reaction tube preferably flow at a higher rate so as to perform a complete mixing of the gases. Particularly, the average velocity is preferably 5 m/sec or more. When the gases flow at a velocity of 5 m/sec or more within the reaction tube, the gases can be satisfactorily mixed within the reaction tube.

**[0034]** The inlet nozzle for introducing the starting material gas into the reaction tube may be a nozzle of giving coaxial parallel flow, oblique flow, cross flow or the like but the present invention is not limited thereto. In general, the coaxial parallel-flow nozzle is inferior in the mixing degree to the nozzle of giving oblique flow or cross flow but is preferably used in view of the design because of its simple structure. For example, in the case of a coaxial parallel-flow nozzle, the starting material gas containing a titanium tetrachloride is introduced into the inner tube and the oxidizing gas is introduced into the outer tube. In view of the mixing of gases, the inner diameter is preferably 50 mm or less, more preferably from 10 to 50 mm.

**[0035]** Salts containing a metallic element are reacted with the above mentioned starting material gas and an oxidizing gas in the present invention.

**[0036]** A metallic element is elements shown in Table 1. The metallic element is preferably a transition metallic element, an alkaline earth metal, an alkali metal element or a metal of Group IIb or IVb.

Table 1

## Elements Defined as Metallic Element

	Ia	IIa	IIIa	IVa	Va	VIa	VIIa	VIII	IB	IIB	IIIB	IVb	Vb	VIb	VIIb	O
1																
2	3 Li	4 Be									5 B					
3	11 Na	12 Mg									13 Al	14 Si	15 P			
4	19 K	20 Ca	21 Sc		23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te
6	55 Cs	56 Ba	(LAN)	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po
7	87 Fr	88 Ra	(ACT)												85 At	

Lanthanide (rare earth)	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinoid	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

[0037] The salt containing a metallic element may be at least one freely selected from a hydroxide, a halide, a nitrate,

a sulfate, a carbonate and an organic acid salt of the above-mentioned metal elements.

[0038] The salt containing a metallic element may be fed into a reactor in the solution or slurry state but is preferably fed in the solution state.

[0039] The solvent of a solution or a slurry is preferably a solvent having a boiling point of 40°C or more at an atmospheric pressure. Specific examples thereof include water, methanol, ethanol, propanol, 2-propanol, 1-butanol, 2-butanol, acetone, methyl ethyl ketone, dibutyl ether, N,N-dimethylformamide, dimethyl sulfoxide, formic acid, acetic acid, ethyl acetate, benzene, toluene, hexane and octane. Among these, in view of polarity and handleability, water is preferred. If the boiling point is less than 40°C, the solvent may be evaporated within the feeding nozzle and this is not preferred.

[0040] The solution or slurry may be fed at a position upstream from the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas or may be fed between the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas and the position 200 mm downstream from the point, according to the flowing direction. If the feeding point is more downstream, the additive distribution in the produced oxide disadvantageously becomes non-uniform.

[0041] The solution or slurry may also be fed by the dropwise addition or atomization to the reaction mixture of the starting material gas containing titanium tetrachloride and the oxidizing gas. In view of uniform mixing, the solution or slurry is preferably fed in the atomized state.

[0042] The reaction within the reaction tube is an exothermic reaction. If the reaction temperature is higher than the sintering temperature of the produced ultrafine particulate complex oxide containing titanium oxide, unless the produced fine particles are rapidly cooled, sintering thereof proceeds to give grown particles. The reaction temperature is also preferably 600°C or more. If the reaction temperature is less than this range, the reactivity is bad, the addition yield of metal is low and fine particles are difficult to form. In the present invention, it is preferred that the preheating temperature of starting material gas and the amount of solution or slurry of the metal added are adjusted, the reaction temperature is set to 600°C or more, the high-temperature residence time in excess of 600°C within the reaction tube is set to 1.0 second or less, and the particles after the reaction are rapidly cooled.

[0043] For rapidly cooling the particles after the reaction, a method of introducing a large amount of cooling air or gas such as nitrogen into the mixture after the reaction or a method of spraying water thereon may be used.

[0044] Fig. 1 is a schematic view roughly showing an example of a reaction tube with a coaxial parallel-flow nozzle for use in the production of an ultrafine particulate composite oxide of the present invention. The starting material gas containing titanium tetrachloride is pre-heated to a predetermined temperature by a preheating unit 2 and introduced into the reaction tube 4 through the inner tube of a coaxial parallel-flow nozzle 1. The oxidizing gas is preheated to a predetermined temperature by the preheating unit 2 and introduced into the reaction tube 4 through the outer tube of the coaxial parallel-flow nozzle 1. The salt solution or slurry containing a metallic element is introduced into the reaction mixture of the titanium tetrachloride and the oxidizing gas from the outside of the nozzle through an inlet nozzle 3. The gases and the salt solution or slurry containing a metallic element introduced into the reaction tube are mixed, reacted, rapidly cooled by a cooling gas and thereafter, transferred to a bag filter 5 where the ultrafine particulate complex oxide is collected. A dechlorinating treatment was performed by heating the collected particles in an oven at 300 to 600 °C for a half an hour to 4 hours in an air atmosphere.

[0045] The starting material gas containing titanium tetrachloride may be used in the form of a 100 vol% titanium tetrachloride gas as it is but is preferably charged after diluting it with an inert gas to a concentration of 10 to less than 100 vol%, preferably from 20 to less than 100 vol%. By using a gas of 10 vol% or more as a starting material, generation of uniform nuclei increases and the reactivity is enhanced. The inert gas is selected from those which are not reactive with titanium tetrachloride and not oxidized. To speak specifically, the diluting gas is preferably nitrogen, argon or the like.

[0046] The ultrafine particulate complex oxide obtained by the production process of the present invention is described below. The average primary particle size of the ultrafine particulate complex oxide of the present invention is from 0.008 to 0.3 µm, preferably from 0.015 to 0.15 µm.

[0047] As an index (the evaluation method is described later) for sintering resistance of the ultrafine particulate complex oxide, the decrease ratio of BET specific surface area after the heating is evaluated, as a result, the decrease ratio of BET specific surface area of the fine particulate complex oxide containing a titanium-oxygen-metal bond is 20% or less after the heating at 700°C for 1 hour.

[0048] The ultrafine particulate complex oxide obtained by the production process of the present invention may take a core/shell structure preferably having a dissimilar metal oxide crystal structure. For example, in the case of a titanium-metal ultrafine particulate complex oxide containing a mixed crystal state where a titanium-oxygen-dissimilar metal bond is present within the primary particle, a structure such that a TiO<sub>2</sub> phase is rich in the core and a dissimilar metal oxide phase is rich in the shell is observed.

[0049] The ultrafine particulate complex oxide of the present invention can be singly used for a pigment or a dielectric starting material or as a composition containing the complex oxide, used for various compositions and products such

as cosmetic, cloth, ultraviolet-shielding agent, abrasive, silicon rubber or paper. The ultrafine particulate complex oxide of the present invention can also be used as a photocatalytic powder material controlled in the photocatalytic effect.

#### Best Mode for Carrying Out The Invention

[0050] The present invention is described in greater detail below by referring to the Examples, however, the present invention is not limited to these examples.

#### [Evaluation of Sintering Resistance]

[0051] The decrease ratio of BET specific surface area after heating is employed as an index for evaluating sintering resistance of the ultrafine particulate complex oxide of the present invention.

[0052] In an alumina-made crucible, 1 g of a starting powder material was charged and in a Siliconit oven, heated at 700°C for 1 hour. After cooling to room temperature, the BET specific surface area was measured. Assuming that the BET specific surface area of the starting powder material is B1 (m<sup>2</sup>/g) and the BET specific surface area after the heating is B2 (m<sup>2</sup>/g),

Decrease ratio of BET specific surface area =

$$\{1-(B2/B1)\} \times 100 (\%)$$

As the decrease ratio of BET specific surface area is smaller, the sintering resistance is judged higher.

#### (Evaluation of Mixed Crystal State)

[0053] In the present invention, XPS (X-ray photoelectron spectroscopy) is employed for confirming the mixed crystal state. The details thereon are described in A. Yu. Stakheev et al., *J. Phys. Chem.*, 97(21), 5668-5672 (1993), and the like.

#### Example 1

[0054] A reaction tube shown in Fig. 1 whose inner tube of a coaxial parallel-flow nozzle had a diameter of 20 mm was used. 11.8 Nm<sup>3</sup>/hr (N means a standard state, hereinafter the same) of gaseous titanium tetrachloride in a concentration of 100 vol% and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 20 Nm<sup>3</sup>/hr of water vapor were preheated to 1,100°C and 1,000°C, respectively, and then titanium tetrachloride was introduced into the inner tube of a coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 53 m/sec and 50 m/sec, respectively. At this time, 3.7 kg/hr of an aqueous 20% zirconium oxychloride solution was sprayed from the outer circumferential part of the coaxial parallel-flow nozzle.

[0055] The inside velocity at a reaction temperature of 900°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.8 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0056] The thus-obtained titanium oxide had a BET specific surface area of 22 m<sup>2</sup>/g and an average primary particle size of 0.08 μm, and 0.8% of zirconium was detected. By XPS, a titanium-oxygen-zirconium bond was recognized.

[0057] The decrease ratio of BET specific surface area (hereinafter referred to as ΔB) after 700°C for 1 hour heating was 12%.

#### Example 2

[0058] By using a reaction tube shown in Fig. 1 whose inner tube of the coaxial parallel-flow nozzle had a diameter of 20 mm, a starting material gas containing titanium tetrachloride obtained by mixing 10.6 Nm<sup>3</sup>/hr of gaseous titanium tetrachloride and 6.0 Nm<sup>3</sup>/hr of nitrogen and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 30 Nm<sup>3</sup>/hr of water vapor were preheated to 1,100°C and 1,100°C, respectively, and then the gas containing titanium tetrachloride was introduced into the inner tube of the coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 74 m/sec and 66 m/sec, respectively. At this time, 7.1 kg/hr of an aqueous 20% chromium trichloride solution was sprayed from the outer circumferential part of the coaxial parallel-flow nozzle.

[0059] The inside velocity at a reaction temperature of 1,000°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.9 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0060] The thus-obtained titanium oxide had a BET specific surface area of 34 m<sup>2</sup>/g and an average primary particle size of 0.04 μm, and 1.1% of chromium was detected. By XPS, a titanium-oxygen-chromium bond was recognized. The ΔB was 10%.

### Example 3

[0061] By using a reaction tube shown in Fig. 1 whose inner tube of the coaxial parallel-flow nozzle had a diameter of 24 mm, a starting material gas containing titanium tetrachloride obtained by mixing 10.6 Nm<sup>3</sup>/hr of gaseous titanium tetrachloride and 10.0 Nm<sup>3</sup>/hr of nitrogen and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 30 Nm<sup>3</sup>/hr of water vapor were preheated to 1,050°C and 1,100°C, respectively, and then the gas containing titanium tetrachloride was introduced into the inner tube of the coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 64 m/sec and 36 m/sec, respectively. At this time, 6.5 kg/hr of an aqueous 20% magnesium nitrate solution was sprayed from the outer circumferential part of the coaxial parallel-flow nozzle.

[0062] The inside velocity at a reaction temperature of 1,000°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.9 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0063] The thus-obtained titanium oxide had a BET specific surface area of 40 m<sup>2</sup>/g and an average primary particle size of 0.04 μm, and 0.5% of magnesium was detected. By XPS, a titanium-oxygen-magnesium bond was recognized. The ΔB was 13%.

### Comparative Example 1

[0064] By using a reaction tube shown in Fig. 1 whose inner tube of the coaxial parallel-flow nozzle had a diameter of 20 mm, 11.8 Nm<sup>3</sup>/hr of gaseous titanium tetrachloride in a concentration of 100 vol% and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 20 Nm<sup>3</sup>/hr of water vapor were preheated to 1,000°C and 900°C, respectively, and then gaseous titanium tetrachloride was introduced into the inner tube of the coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 49 m/sec and 50 m/sec, respectively.

[0065] The inside velocity at a reaction temperature of 1,000°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.8 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0066] The thus-obtained titanium oxide had a BET specific surface area of 20 m<sup>2</sup>/g and an average primary particle size of 0.08 μm. The ΔB was 35% and this reveals that the sintering readily occurs as compared with the titanium oxide having similar specific surface area and particle size of Example 1.

### Comparative Example 2

[0067] By using a reaction tube shown in Fig. 1 whose inner tube of the coaxial parallel-flow nozzle had a diameter of 20 mm, a starting material gas containing titanium tetrachloride obtained by mixing 10.6 Nm<sup>3</sup>/hr of gaseous titanium tetrachloride and 6.0 Nm<sup>3</sup>/hr of nitrogen and a mixed gas containing 8 Nm<sup>3</sup>/hr of oxygen and 30 Nm<sup>3</sup>/hr of water vapor were preheated to 1,000°C and 800°C, respectively, and then the gas containing titanium tetrachloride was introduced into the inner tube of the coaxial parallel-flow nozzle and a mixed gas containing oxygen and water vapor was introduced into the outer tube at velocities of 68 m/sec and 51 m/sec, respectively.

[0068] The inside velocity at a reaction temperature of 1,000°C within the reaction tube was 10 m/sec as calculated. For controlling the high-temperature residence time within the reaction tube to 0.9 seconds or less, a cooling air was introduced into the reaction tube after the reaction and then, the produced powder material was collected using a Teflon-made bag filter. Thereafter, a dechlorinating treatment was performed by heating the particles in an oven at 500°C for 1 hour in an air atmosphere.

[0069] The thus-obtained titanium oxide had a BET specific surface area of 36 m<sup>2</sup>/g and an average primary particle

size of 0.04  $\mu\text{m}$ . The  $\Delta B$  was 39% and this reveals that sintering readily occurs as compared with the titanium oxide having similar specific surface area and particle size of Example 2.

#### Industrial Applicability

[0070] According to the present invention, the starting material gas containing titanium tetrachloride and the oxidizing gas are each pre-heated to 700°C or more and reacted with a solution or slurry of a salt containing a metallic element, whereby an ultrafine particulate complex oxide containing titanium oxide having excellent sintering resistance and a BET specific surface area of 5 to 200  $\text{m}^2/\text{g}$  and containing primary particles in a mixed crystal state can be obtained by a one-stage reaction.

[0071] According to the production process of the present invention, the cracking step and the like can be dispensed with or even if required, the load of equipment is very small, thus, practically valuable ultrafine particulate complex oxide containing titanium oxide can be produced very easy and simple and industrially advantageously. Furthermore, according to the method of the present invention, the ultrafine particulate complex oxide whose sintering property or photoactivity are suppressed or controlled can be obtained.

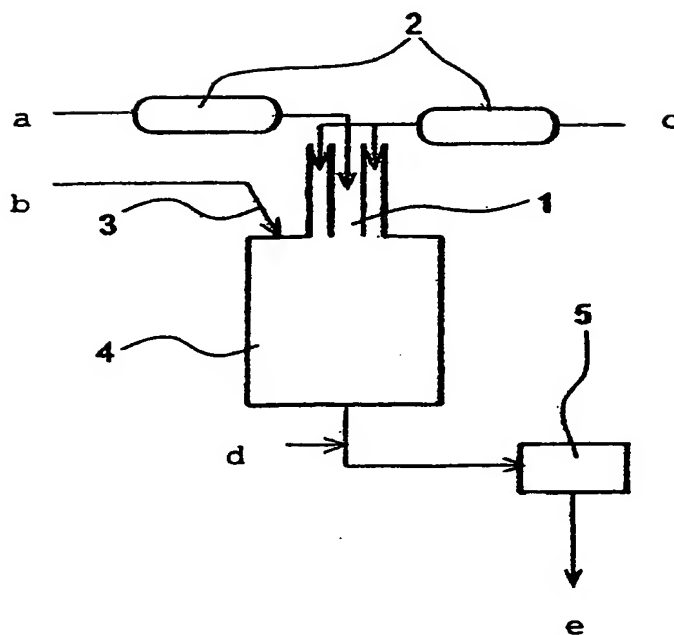
#### Claims

1. A process for producing ultrafine particulate complex oxide containing titanium oxide, comprising vapor-phase producing a complex oxide containing titanium oxide having a BET specific surface area of 5 to 200  $\text{m}^2/\text{g}$ , wherein a starting material gas containing titanium tetrachloride and an oxidizing gas, each gas being preheated to 700°C or more, are reacted with a solution or a slurry of a salt containing a metallic element.
2. The process for producing a complex oxide containing titanium oxide as described in claim 1 above, wherein the complex oxide contains a titanium-oxide-metallic element bond.
3. The process for producing a complex oxide containing titanium oxide as described in claim 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing a transition metallic element.
4. The process for producing a complex oxide containing titanium oxide as described in claim 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing an alkaline earth metal.
5. The process for producing a complex oxide containing titanium oxide as described in claim 1 or 2, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing an alkali metal.
6. The process for producing a complex oxide containing titanium oxide as described in claim 1 or 2 above, wherein the salt containing a metallic element is at least one salt selected from the group consisting of a hydroxide, a halide, a nitrate, a sulfate, a carbonate and an organic acid salt each containing a metal of Group IIb or IVb.
7. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 6 above, wherein the solvent of the solution or slurry having a boiling point of 40°C or more at an atmospheric pressure is used.
8. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 7 above, wherein the solution or slurry is fed at a position upstream from the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas.
9. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 7 above, wherein the solution or slurry is fed between the point of initiating the reaction of the starting material gas containing titanium tetrachloride with the oxidizing gas and the position 200 mm downstream from the point.
10. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 9, wherein the solution or slurry is fed in the atomized state.

11. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 10 above, wherein the reaction is performed by feeding the starting material gas containing titanium tetrachloride and the oxidizing gas, each gas being preheated at 700°C or more, to a reaction tube each at a velocity of 10 m/sec or more.
12. The process for producing a complex oxide containing titanium oxide as described in claim 11 above, wherein the reaction is performed by allowing the starting material gas containing titanium tetrachloride and the oxidizing gas to stay in the reaction tube under a temperature condition such that the temperature within the reaction tube exceeds 600°C, for a time period of 1.0 second or less.
13. The process for producing a complex oxide containing titanium oxide as described in claim 11 or 12 above, wherein the average velocity of the starting material gas within the reaction tube is 5 m/sec or more.
14. The process for producing a complex oxide containing titanium oxide as described in any one of claim 11 to 13 above, wherein a turbulence is generated upon feeding of the starting material gas containing titanium tetrachloride and the oxidizing gas, each gas being preheated, into the reaction tube.
15. The process for producing a complex oxide containing titanium oxide as described in any one of claims 11 to 14 above, wherein the starting material gas containing titanium tetrachloride and the oxidizing gas are fed into the reaction tube through a coaxial parallel-flow nozzle and the inner tube of the coaxial parallel-flow nozzle has an inside diameter of 50 mm or less.
16. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 15, wherein as the starting material gas containing titanium tetrachloride, gaseous titanium tetrachloride and a gas containing 10 vol% or more of titanium tetrachloride diluted by an inert gas are used.
17. The process for producing a complex oxide containing titanium oxide as described in any one of claims 1 to 16 above, wherein the starting material gas containing titanium tetrachloride and the oxidizing gas each is preheated at 1,000°C or more.
18. An ultrafine particulate complex oxide containing titanium oxide, which is produced by the production process as described in any one of claims 1 to 17 above.
19. An ultrafine particulate complex oxide containing titanium oxide, which is an ultrafine particulate complex oxide having a BET specific surface area of 5 to 200 m<sup>2</sup>/g.
20. An ultrafine particulate complex oxide containing titanium oxide as described in claim 19, which is in the mixed crystal state of allowing a titanium-oxide-metallic element bond to be present within a primary particle.
21. An ultrafine particulate complex oxide containing titanium oxide as described in any one of claims 18 to 20 above, wherein the average primary particle size is from 0.008 to 0.3 μm.
22. An ultrafine particulate complex oxide containing titanium oxide as described in any one of claims 18 to 21, wherein the decrease ratio of the BET specific surface area after heating at 700°C for 1 hour is 20% or less.
23. A composition comprising one ultrafine particulate complex oxide, which contains ultrafine particulate complex oxide containing titanium oxide as described in any one of claims 18 to 22 above.



Fig.1



- a...TITANIUM TETRACHLORIDE (AND DILUTING GAS)
- b...AQUEOUS SALT SOLUTION CONTAINING METAL ELEMENT
- c...OXYGEN AND WATER VAPOR
- d...COOLING AIR
- e...FINELY PARTICULATE COMPOSITE OXIDE CONTAINING  
TITANIUM OXIDE

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP01/03449

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. <sup>7</sup> C01G23/07		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl. <sup>7</sup> C01G23/07		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2001 Kokai Jitsuyo Shinan Koho 1971-2001 Jitsuyo Shinan Toroku Koho 1996-2001		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3208866 A (E.I. du Pont de Nemours and Company), 28 December, 1965 (28.12.65), Claims; examples I-III; tables I, II (Family: none)	1-23
A	JP 8-502945 A (E.I. du Pont de Nemours and Company), 02 April, 1996 (02.04.96), Claims; working example & US 5201949 A & WO 9410089 A & EP 667836 A	1-23
A	JP 10-251021 A (Showa Denko K.K.), 22 September, 1998 (22.09.98), Claims; Par. Nos. [0018], [0019]; working example; table 1 (Family: none)	1-23
X	JP 9-315818 A (KOSE Corporation), 09 December, 1997 (09.12.97), Claims; working example (Family: none)	19-23
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
"A" Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the international search 24 July, 2001 (24.07.01)		Date of mailing of the international search report 07 August, 2001 (07.08.01)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP01/03449

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 11-197513 A (Sumitomo Osaka Cement Co., Ltd.), 27 July, 1999 (27.09.99), Claims; Par. No. {0027}; working example (Family: none)	19-23

Form PCT/ISA/210 (continuation of second sheet) (July 1992)